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RESEARCH PAPER

A model of supplying poplar wood for Iranian paper & wood factories

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Abstract: The objective of this research is to design a method for an appropriate alternative to supply poplar wood as raw material for wood and paper factories in Iran. Due to the destruction of the forests and lack of proper plantation, replacement of the forest wood by the fast growing wood is vital to satisfy all requirements of these factories. A hierarchy was used to prioritize benefits, opportunities, costs and risks (BOCR) using the Analytic Hierarchy Process (AHP) ratings approach. To evaluate the "control criteria" of the system, a control hierarchy was also created and prioritized by applying the Analytic Network Process (ANP). A total of four major control criteria in the system are prioritized where each one controls a network structure evaluated by using ANP. The final synthesis results of the system showed that internal poplar tree farming supplied by the forest product factories was the best choice among three potential alternatives (factory procurement, external procurement and mix procurement).

Keywords: Poplar wood; wood and paper industries; BOCR (Benefits, Opportunities, Costs and Risks); ANP (Analytic Network Process); AHP (Analytic Hierarchy Process)

Introduction

Demand for forest products, including particleboard, fiberboard and paper, is increasing in Iran, while Iranian paper & wood factories cannot produce sufficient products to fulfill such need. The most crucial barrier for the domestic forest product manufacturers is inadequate supply of raw materials. Therefore, nowadays these industries have a major problem regarding to the raw material procurement. However, some of these alternatives must be established within a period of five to ten years. Domestic wood raw materials for the industries come from different sources including forest resources. The raw materials, such as poplar, birch trees and softwood species are also imported abroad. In general, Iran is not rich in forest resources, compared to other countries. There are the areas of 1.2×10^6 hm^2 of trading forests in north of Iran and the amount of wood exploitation from these areas is limited. To solve this problem, the analytic network process (ANP) developed by Saaty (2001a) was used to be an appropriate tool. The classical analytical methods, such as Simple Additive Weighting method (SAW), Technique for order-Preference by Similarity to ideal Solution (TOPSIS), etc. do not work well because many aspects of these projects, especially, the social parts can not be quantified properly. Furthermore, these methods are usually developed based on some simplifying assumptions or these problems can not be solved analytically otherwise. That is why some real world problems are far from the models constructed on the basis of these restrictive assumptions. The ANP has been applied for solving other economic problems. Piantanakulchai (2005) applied ANP for prioritizing the potential highway alignments. ANP is also used as a novel approach to tackle the selected problem how to make the decision on national missile defense program. By applying an ANP model, deploying National Missile Defense (NMD) alternative is the best alternative (Saaty 2001d). Azis (2003) applied ANP for making decision on financial arrangement in Asia zone. The purpose of the study by Ilker et al. (2004) is to develop a multi criteria model of organic food marketing strategies, which are believed to improve the domestic market. The Analytic Network Process is utilized to construct such a model. Cevik et al. (2004) presented an integrated framework based on ANP and utilizing Delphi Technique to select an enterprise resource planning (ERP) system. There is also one example, which is making decision regarding the establishment of commercial ties with China (Saaty et al. 2001b). They concluded that Preferred Normal Trade Relations (PNTR) was the best choice. The proposed model is implemented in a company of electronic (Gencer et al. 2007). The case study helps to verify that ANP is an effective and efficient tool (Habib et al. 2007). ANP model is used for locating facilities strategically (Partovi, 2006). ANP model has been used for selection of the appropriate energy policy for Turkey (Ulutas, 2005), for product mix planning in semiconductor fabricator (Chang, et al, 2005). The objective of this research is to design a method to establish plywood and veneer plants in Iran (Azizi and

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Modarres, 2007). This paper is the result of an extensive study to select the optimal alternative for supplying poplar wood in Iranian forest product factories.

Analytic network process (ANP)

ANP, a generalization of the Analytic Hierarchy Process (AHP) method for multi criteria decision, provides an even broader framework for decision in complicated environments. Since the most suitable techniques for our study seems to be the analytic network process (ANP), we review it briefly in this study.

The alternatives

The alternatives which are evaluated in current research are three sub sections as follows:

First alternative is procurement of poplar wood from internal resources. If poplar were supplied by wood and paper factories, the purchase of wood as raw material from selling markets would not be required.

Second alternative is procurement of poplar wood from foreign resources. The raw material is procured via governmental organizations or private sections that planted poplar tree. The factories only purchase raw material from the market.

Third alternative is procurement of poplar wood in mix. Essential raw material is procured both by the factories and governmental & private sections.

Prioritizing benefits, opportunities, costs and risks (BOCR) as merits

For selecting the most appropriate alternatives to supply poplar wood in forest product industries, the best approach is to divide the criteria into favorable and unfavorable categories. The decision makers consider the favorable criteria as benefits and the unfavorable criteria as costs. The possible events are also divided into opportunities criteria and risks criteria, depending whether they are considered to be positive or negative (Saaty 2001a). In this research the merits of benefits, costs, opportunities, and risks were weighted by five general factors, liable to one of the following broad categories: environmental factors (related to wood and non-wood plantation issues), cultural & social factors (divided into two factors, literacy and culture level, population growth), economic factors, external commerce factors (related to wood import regulations, which is used in wood and paper factories, for example poplar wood) and governmental regulation factors (related to poplar plantation regulations in the country). Ratings of general factors were done by pair-wise comparisons of the lower level factors, which are summed up for the main factors at the top level. Since BOCR are not equally important, it is necessary to prioritize them. The priority of the above mentioned merits are reported in Table 1. Four hierarchies for the merits of benefits, costs, opportunities, and risks, are introduced.

Benefits to the factories and region

Benefits are favorable and inevitable criteria**.** In current research, benefits are included four main criteria as follows:

Better access to the raw material: enough accessibility to the raw material gives rise to stock of available raw material in the location. Accordingly, quality and price of the raw material are improved in site of the factory.

This criterion was divided in 3 sub criteria: *Price:* Actually, low price of the raw material will affect on the profit increase because raw material cost has more share in cost price. *Quality:* Higher quality of the raw material will increase the customer's satisfaction level and market share of the product. *Quantity:* procurement of raw material with respect to requirements of the factories influences on the perseverance of the production process.

Reduction of pressure on the forests: Plantation of poplar wood reduces exploitation of the forests and also improves climate conditions of the region. This criterion was divided in two sub criteria as follows: *Reduction of forests exploitation rate:* with respect to irregular exploitation of the forest resources, securely, plantation of fast growing wood species, similar to poplar species, gives rise to decrease of pressure on the forests. *Improvement of climate conditions:* fast growing wood species, for example, poplar, has an important role in the reduction of climate pollution.

Improvement of employment status: Plantation of poplar and development of its industry lead to increase in local employment and income and manpower absorption. These situations give rise to economic growth of the region.

Poplar plantation development: Poplar plantation development in the region will have an important role in the procurement of utilized raw material in low price.

Table 1. Priority rate for the merits (Benefits, Costs, Opportunities and Risks)

General factors		Risks	Opportunities	Costs	Benefits
Economic (0.49)		High	High	Very high	Very high
Governmental regulations(0.214)		High	High	High	High
External commerce (0.065)		Medium	Low	Low	Medium
Environmental: cultivation wood and other (0.17)		High	Medium	Medium	Very high
Cultural & social (0.061)	Population growth (0.25)	Very low	Medium	Low	High
	Literacy level(0.75)	Very low	Medium	Very low	Medium
Overall priorities		0.198	0.181	0.279	0.342

Notes: very high (1), high (0.51), medium (0.252), low (0.124), very low (0.065). The data such as 1, 0.51,…, represented weighing values of qualitative attributes in comparison with together.

Opportunities to the factories and region

Opportunities are possible and positive events. In this research the opportunities were divided in four main criteria as follows:

Investment absorption: industry development of the region eventuates in the increasing interest of the investors for investment in the region. *Capital return:* The rate of capital return for

planting poplar tree is faster than that of other species, because poplar is fast growing species in comparison with other species. *Generation of proper base for investment:* with respect to advantages of poplar, the number of investors in the field of poplar plantation will increase. The potentiality of economic development in the region will be procured. In this regard, west and northwestern Iran will have proper situation for the investment.

Optimal utilization of the low productivity lands: poplar tree is possible in the lands, which are not favorable for agriculture products. This criterion is divided in two subsections as follows: *Using of the lands with high slope:* The area with higher slope is possible to plant poplar tree, whereas, is not possible for farming. *Using of the lands which is not used in agriculture section:* sandy, clay, a deep and soft land is possible for planting poplar.

Development of local cooperatives: economic development of the region eventuates in development of the local cooperative forest product industries which absorb the man force and local ability of the region. This criterion is divided in two subsections: *Public partnership prosperity:* development of the industry with respect to employment increment and economic growth eventuates in the promotion of the local people for participating in improvement of economic status. *The better facility allocation potentiality:* with the development of the industry concerning the employment increment and its progress via local cooperatives, the possibility will be provided for the optimal use of especial facilities, which is considered by governmental organization.

Sale market progress: Poplar plantation gives rise to sale market progress in the country. This criterion is divided in two subsections: *Competitive market generation based on quality:* sale market progress eventuates in the seller's competition for procuring high quality poplar wood. Competitive market gives rise to progress of sale. *Price stabilization:* internal investors via poplar plantation prevent excess fluctuation of poplar price in internal markets and price stabilization eventuates in the price stabilization of poplar wood in the country.

Costs to the factories and region

Costs are unfavorable and inevitable criteria. In this research, the costs were divided in three main criteria as follows:

Plantation, preservation and exploitation costs: the costs of supplying poplar wood have three costs, which include plantation phase cost, preservation phase cost and exploitation phase cost. This criterion is divided in six subsections: *Energy cost:* The supply of poplar wood needs water, electricity and fuel. *Slip supply cost:* The purchase of slip is main cost which influences the cost price of poplar supply. *Personnel cost:* poplar supply needs manpower to plant, preserve and utilize. *Machine and equipment costs*: using of machine for plantation, cultivation and exploitation will be included procurement and depreciation costs of the machines. *Storage cost:* storage of poplar after exploiting affects on manager's decision for procuring raw material. *Chemical material and fertilizer costs:* this cost includes fertilizer and chemical material price, giving poison and fertilizer distribution costs

Transportation, evacuation and loading costs of sale center: This cost includes transportation and evacuation and loading cost of obtainable trees to sale centers

Land supply cost for poplar cultivation: cost of the land is the most important cost for planting poplar trees.

Risks to the factories and region

Risks are possible and negative events. In current research, the risks include five main criteria as follows:

●Improper climate situations: improper climate situations eventuate in improper tree growth and primitive investment losses. This criterion is divided in two sub criteria as follows: *Improper growth of the trees:* Improper tree growth gives rise to undesirable quality of the obtained wood. *Primitive investment damage:* due to the mitigated utilization, the primitive investment will be damaged.

●Existence of plagues: plantation of poplar encountered often wood plagues, such as xylophagous and phyllophagous plagues.

● Inaccessibility of proper slip: impossibility of essential slip supply is high risk in the industry.

●Lack of financial support: shortage of financial resources in all the periods results in income damage and probable profit decrease.

●Market improper situation: non-equalization demand & supply for poplar wood in the country lead to intense fluctuation in prices.

Prioritizing sub criteria of the merits and alternatives

Establishment of statistical method and calculation of rating coefficients

After the hierarchy is drawn up for criteria and sub-criteria, an appropriate alternative (Analytic Hierarchy Process) influences the supply of poplar wood as raw material for wood and paper factories. After the questionnaire is prepared as the two-by-two comparison of criteria and sub-criteria, the opinions of the experts will be asked about the priority rate of these criteria and sub-criteria against each other in the form of dual comparison matrices. Then we will compare the priority rate of each criterion and sub- criterion. First geometric average was calculated for each one of the matrix cells by the following equation (Saaty 2000).

$$\alpha_{12} = (a_{12}1 \times a_{12}2 \times \ldots \times a_{12}N)^{1/N} \quad (1)$$

where, α_{12} is the result of group judgment on the subject of a_{12}, a_{12}: judgment's result of each decision maker; N is the number of decision makers.

After the geometric averages of all matrix cells were calculated, the results were normalized and the criterion and sub-criterion weighting value were obtained through integration of the weight of the low-level elements into the weight of the related up-level elements.

With respect to above mentioned merits, the results of geometric averages matrices and weighted super matrix for benefits

criteria and sub criteria were obtained, which were extracted from Super Decisions software (Table 4), and similarly the results for costs, opportunities and risks can be developed. After pair wise comparisons between sub criteria for benefits, costs, opportunities and risks by ANP as well as pair wise comparisons of the criteria and choices against each other, following the above-mentioned merits, the results are reported in Table 2.

Table 2. Synthesized priorities of the 16 criteria, 21 sub criteria and 3 alternatives

Merits	Criteria	Sub criteria	Factory procurement	Mix procurement	External procurement
Benefits (0.342)	Better access to the raw material(0.659)	Price (0.347)	0.71	0.2	0.081
		Quality(0.254)	0.750	0.16	0.083
		Quantity(0.057)	0.247	0.187	0.565
	Reduction of pressure on the forests(0.081)	Reduction of forests exploitation rate(0.011)	0.696	0.226	0.077
		Improvement of climate conditions(0.071)	0.688	0.21	0.098
	Improvement of employment status(0.15)		0.668	0.22	0.111
	Poplar plantation development(0.11)		0.665	0.23	0.097
Benefits normalized			0.685	0.197	0.116
Opportunities (0.181)	Investment absorption (0.586)	Capital return(0.506)	0.706	0.199	0.093
		Generation of proper base for investment(0.08)	0.694	0.172	0.133
	Optimal utilization of low productivity lands (0.19)	Using of the lands with higher slope(0.121)	0.697	0.205	0.096
		Using of the lands which is not used in agriculture section(0.069)	0.72	0.193	0.084
	Development of local cooperatives(0.116)	Public partnership prosperity(0.062)	0.711	0.134	0.153
		The better facility allocation potentiality(0.054)	0.73	0.172	0.09
	Sale market progress (0.109)	Competitive market generation based on quality(0.066)	0.21	0.216	0.57
		Price stabilization(0.043)	0.207	0.23	0.56
Opportunities normalized			0.653	0.194	0.152
Costs (0.279)	Plantation, preservation and exploitation costs(0.607)	Energy supply(0.085)	0.718	0.195	0.086
		Slip supply(0.266)	0. 73	0.181	0.087
		Personnel (0.106)	0.725	0.184	0.09
		Machine and equipment (0.061)	0.713	0.18	0.106
		Chemical material and fertilizer (0.047)	0.687	0.166	0.145
		Storage (0.043)	0.708	0.187	0.103
	Transportation, evacuation and loading cost to sale center (0.076)		0.711	0.171	0.116
	Land supply cost for poplar cultivation (0.318)		0.735	0.174	0.089
Reciprocal costs			0.725	0.179	0.095
Risks (0.198)	Improper climate situations(0.236)	Improper growth of the tree(0.194)	0.725	0.174	0.099
		Primitive investment damage (0.042)	0.724	0.17	0.104
	Lack of financial support(0.162)		0.725	0.162	0.111
	Market improper situation(0.081)		0.214	0.217	0.568
	Existence of plagues(0.143)		0.72	0.199	0.079
	Inaccessibility of proper slip(0.379)		0.715	0.199	0.085
Reciprocal risk			0.679	0.189	

Notes: Data of the parenthesis are weighting value of the criteria and sub criteria which are obtained via two- by- two comparisons with respect to together.

To apply the ANP, the Super Decisions software was used. The Super Decision software implements the Analytic Network Process (ANP) for making decision with dependence and feedback. That is a simple easy-to-use package for constructing decision models with dependence and feedback and computing results using the super matrices of the Analytic Network Process. This software was designed to run in many different computing environments from Windows 3.1/95/98/, Macintosh and Unix systems such as Linux, SGI's, Sun Systems, etc.. There is also a Web version.

In BOCR structure, the following equation is used in calculations (Saaty, 2001c):

$$B = (B_1)\times(O)/(C)\times(R) \quad (2)$$

where, B is the BOCR structure, B_1 is benefits, O is the opportunities, C is costs, and R is the risks.

Final outcome

By integration of the weights of the merits of benefits, costs, opportunities and risks and the weights of choices against the

above mentioned merits, the final scores are reported in Table 3. The choice of factory procurement has the highest priority, and is the most suitable choice to procurement of raw materials (Table 3). Considering the merits in decision, factory procurement has the highest priority and the second and third is mix procurement and external procurement, respectively.

Table 3. Final outcome for priorities of the alternatives

Alternative	Benefits(0.342)	Opportunities(0.181)	Costs(0.279)	Risks(0.198)	Final Outcome Additive	Ranking
Factory procurement	0.685	0.653	0.725	0.679	0.688	1
Mix procurement	0.197	0.194	0.179	0.189	0.1905	2
External procurement	0.116	0.152	0.095	0.131	0.1206	3

Table 4. Results of weighted super matrix for benefits with respect to comparison matrices of sub criteria and alternatives

Cluster node labels		Alternatives			Benefits	Better ability			Criteria
		Mix	Procure external resource	Procure by factory	Benefits	Price	Quality	Quantity	Better ability
Alternatives	Mix	0.00	0.00	0.00	0.00	0.2	0.16	0.18	0.00
	Procure external	0.00	0.00	0.00	0.00	0.08	0.08	0.56	0.00
	Procure factory	0.00	0.00	0.00	0.00	0.71	0.75	0.24	0.00
Benefits	Benefits	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Better ability	Price	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52
	Quality	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38
	Quantity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Criteria	Better ability	0.00	0.00	0.00	0.65	0.00	0.00	0.00	0.00

Continued Table 4.

Cluster node labels		Better ability		Criteria				Decrease pressure	
		Quality	Quantity	Better ability	Decrease pressure	Improvement poplar cultivation	Increase employment	Decrease exploitation	Improvement weather
Better ability	Quality	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00
	Quantity	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
Criteria	Better ability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Decrease pressure	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Improvement poplar cultivation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Increase employment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decrease pressure	Decrease exploitation	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00
	Improvement weather	0.00	0.00	0.00	0.86	0.00	0.00	0.00	0.00

Continued Table 4.

Cluster node labels		Better ability		Criteria				Decrease pressure	
		Quality	Better ability	Better ability	Decrease pressure	Improvement poplar cultivation	Increase employment	Decrease exploitation	Improvement weather
Alternatives	Mix	0.16	0.18	0.00	0.00	0.23	0.22	0.22	0.21
	Procure external	0.08	0.56	0.00	0.00	0.09	0.11	0.07	0.09
	Procure factory	0.75	0.24	0.00	0.00	0.66	0.66	0.69	0.68
Benefits	Benefits	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Better ability	Price	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.00
	Quality	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00
	Quantity	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
Criteria	Better ability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Continued Table 4.

Cluster node labels		Alternatives			Benefits	Better ability			Criteria
		Mix	Procure external resource	Procure by factory	Benefits	Price	Quality	Quantity	Better ability
Better ability	Quality	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38
	Quantity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Criteria	Better ability	0.00	0.00	0.00	0.65	0.00	0.00	0.00	0.00
	Decrease pressure	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00
	Improvement poplar cultivation	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00
	Increase employment	0.00	0.00	0.00	0.1	0.00	0.00	0.00	0.00
Decrease pressure	Decrease exploitation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Improvement weather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Analysis

Benefit analysis

Current section is divided in five sub-sections: Analysis of benefits, opportunities, costs and risks (BOCR) and highest priority. In Table 1, the benefit has the highest important in decision, compared to costs, opportunities and risks, because it has highest weight (0.342). From Table 2, it is implied that “better access to the raw material (0.659)” has the highest priority in terms of benefits. With respect to better access to raw material, “price” is

sub criterion which has the highest weight (0.347) in comparison with other criteria of benefits. In the past decade, governmental organizations adopted non-utilization policy for the Iranian Northern forests due to the forest extravagant exploitation. Accordingly, in future the manufacturers have to procure their wood raw material from another resource. Plantation of poplar wood is one proper way to reach their aims. Accordingly, plantation of poplar wood results in more convenient access to the raw material in the country.

Opportunity analysis

Opportunity has the lowest important in making decision, compared to benefits, costs and risks, because it has lowest weight (0.181), (Table 1). From Table 2, investment absorption (0.586) is the most important criterion in terms of opportunities. Whereas plantation of poplar is one kind of fast-growing species plantation, the investors are interested in investment in the regions. Plantation with higher production volume and rate of capital return will be better.

Cost analysis

Cost is the second merit as shown in Table 1, because it has weighing value of 0.279. With respect to Table 2, plantation, preservation and exploitation costs (0.607) have the highest priority in terms of costs. There is not financial support for supplying slip, therefore supplying slip is highest cost in comparing with other cost criteria.

Risk analysis

Risk is the third merit, because it has weighing value of 0.198 (Table1). As shown in Table 2, inaccessibility of proper slip (0.379) is involved with an important risk. In the country, slips are not produced by scientific methods and are produced via ancient methods by the farmers, hence, there is not access to proper slip and probably, and timely production of the trees will have high risks.

Highest priority analysis

The procurement of poplar wood by the factories with the highest priority is most suitable choice for the factories and region, which has the highest priority (0.685, 0.725, 0.653, and 0.679) (Table 2, 3). The factories only purchase fertile land to plant poplar wood, and they do not need to purchase poplar from sale markets. Therefore, they will obtain highest profit and their costs will decrease. Financial support can be given in credit facilities for planting poplar, procurement of slip or land procurement. Procurement of poplar wood by the factories can decrease the effects of poplar price fluctuations on supply of poplar, accordingly, procurement of the raw material will be stable. Also, application of scientific methods on poplar plantation by the factories gives rise to produce with more productivity.

Conclusion

In this paper, we applied the ANP and BOCR's structures to determine the best alternative for the supply of poplar wood in Iranian wood & paper factories. The results indicated that benefits and costs are more important in making decision, compared to opportunities and risks. Based on benefits, opportunities, costs and risks and their criteria, three alternatives have been synthesized. Finally, the alternative of "procurement of poplar wood by forest product factories" is most suitable choice for the factories and region.

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